

Boiling Heat Transfer

Boiling - Evaporation at a Liquid Solid Interface

* ** very high heat transfer coefficients

- Latent Heat of Vaporization
- Bouyant Force of Vapor

Excess Temperature, ΔT_e

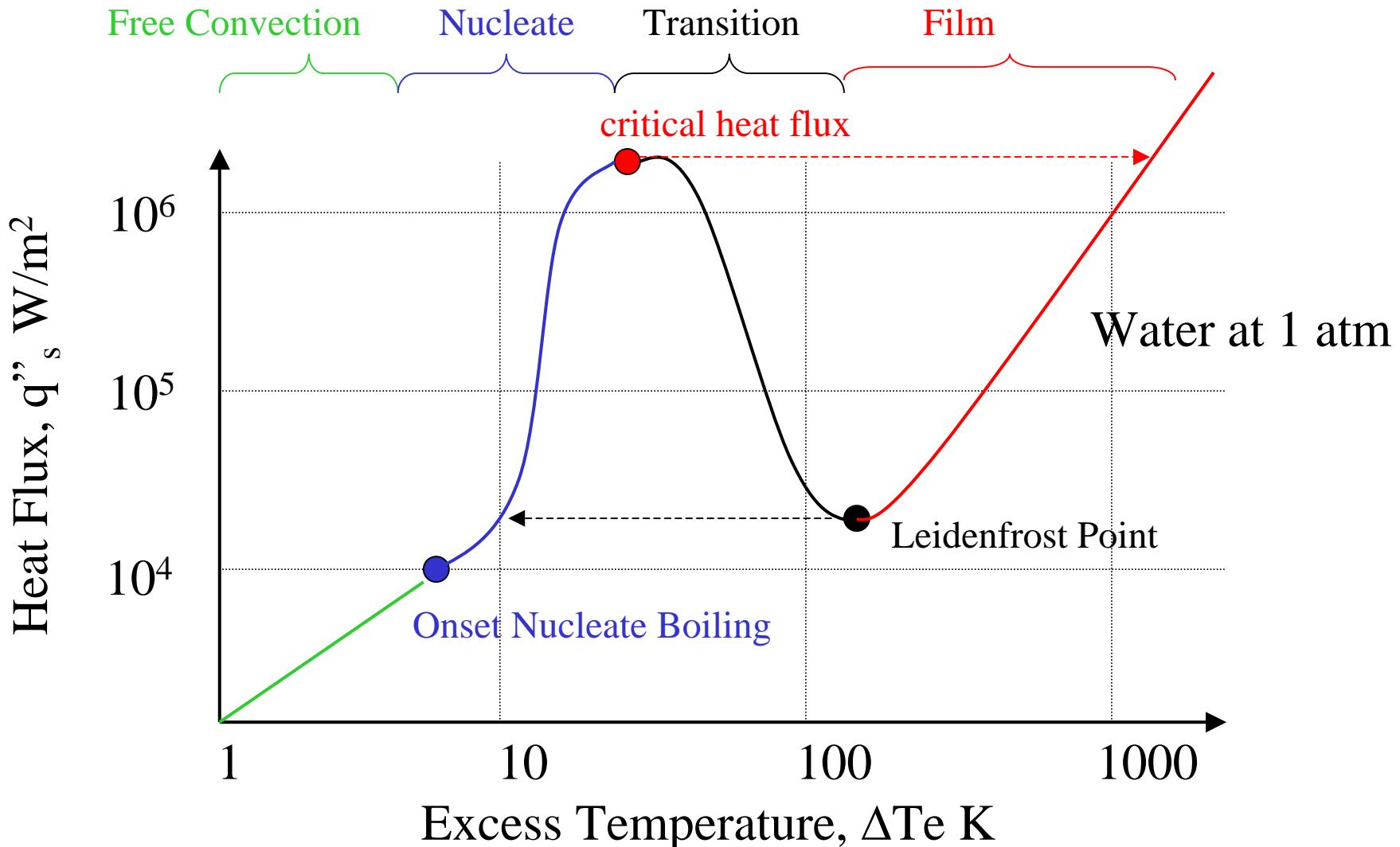
$$q_s'' = h(T_s - T_{sat}) = h\Delta T_e$$

Free Convection (Pool Boiling) or Forced Convection Boiling

Saturated or Subcooled Boiling

- * during subcooled boiling the temperature of the liquid is below the saturation temperature

Modes of Pool Boiling



Estimate the heat transfer coefficient for pool boiling at the critical heat flux, and onset of nucleate boiling

The Boiling Crisis

Critical Heat Flux

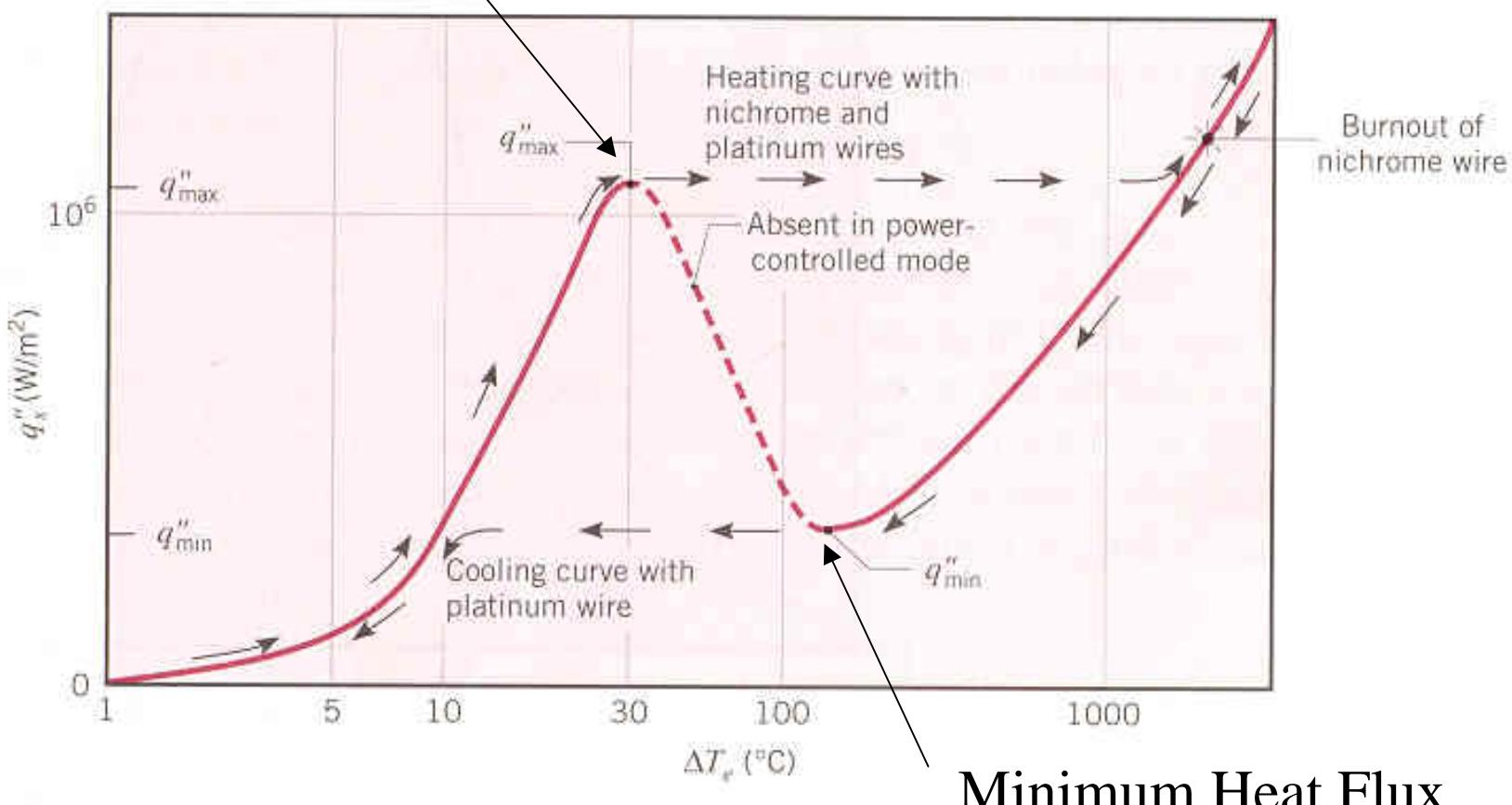
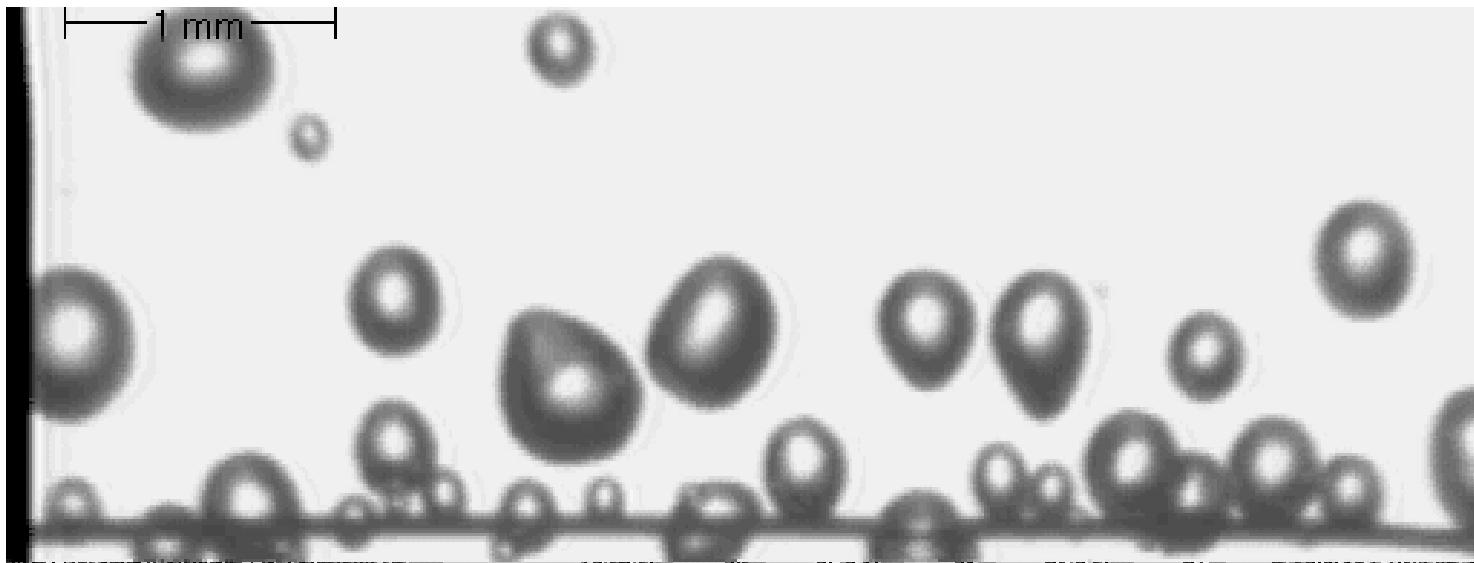


FIGURE 10.3 Nukiyama's boiling curve for saturated water at atmospheric pressure.

Nucleate Boiling

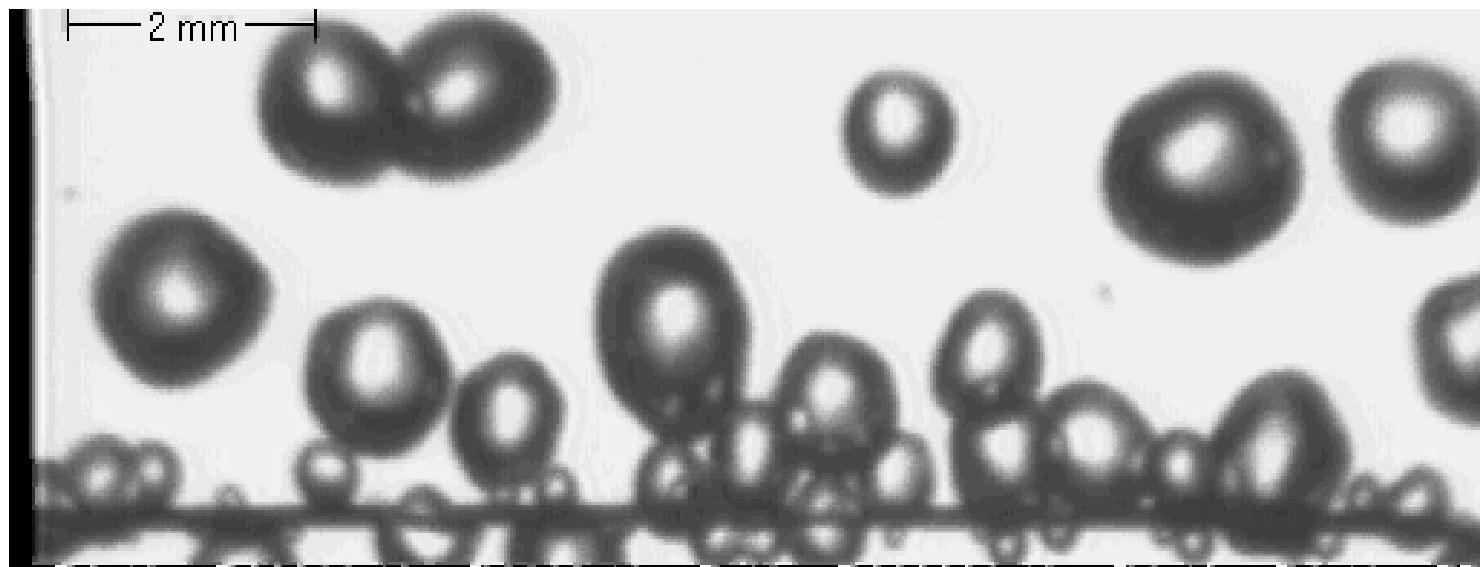


S.M. You, 2002, <http://www-heat.uta.edu/visualization/visualization.html>

Correlation for Nucleate Pool Boiling

$$q_s'' = \mu_l h_{fg} \left[\frac{g(\rho_l - \rho_g)}{\sigma} \right] \left(\frac{c_{P,l} \Delta T_e}{C_{S,f} h_{fg} \text{Pr}_l^n} \right)$$

Critical Heat Flux

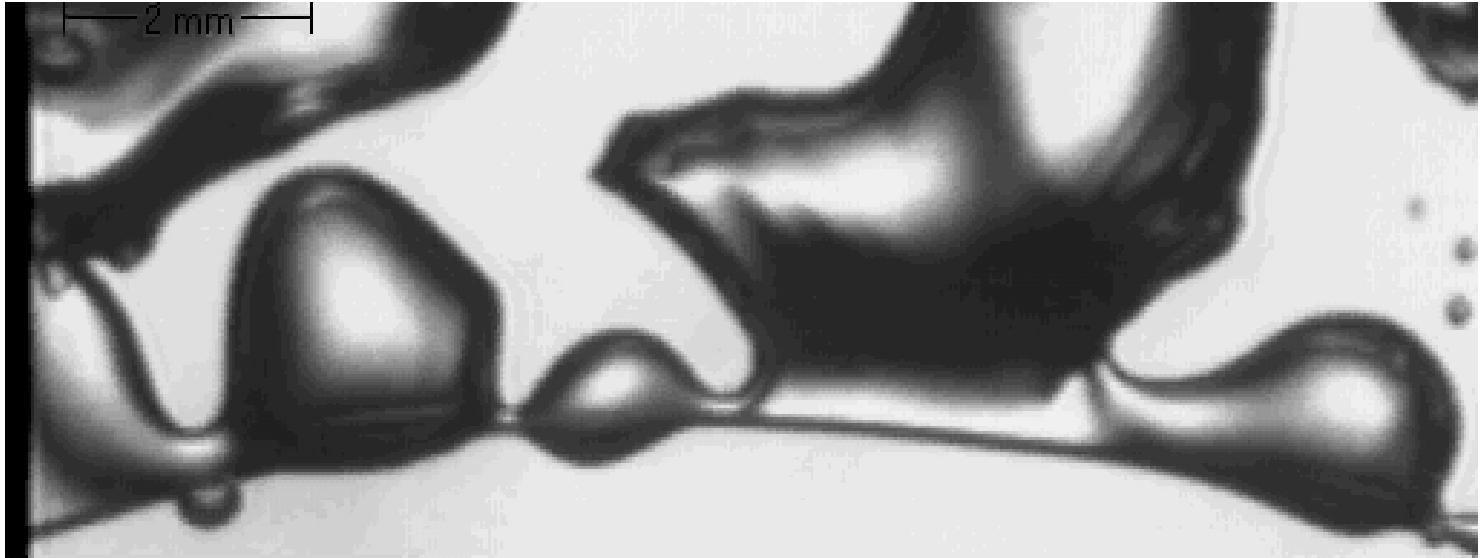


S.M. You, 2002, <http://www-heat.uta.edu/visualization/visualization.html>

Correlation CHF Nucleate Pool Boiling

$$q_{\max} = 0.149 h_{fg} \rho_v \left[\frac{\sigma g (\rho_l - \rho_v)}{\rho_v^2} \right]^{1/4}$$

Film Boiling

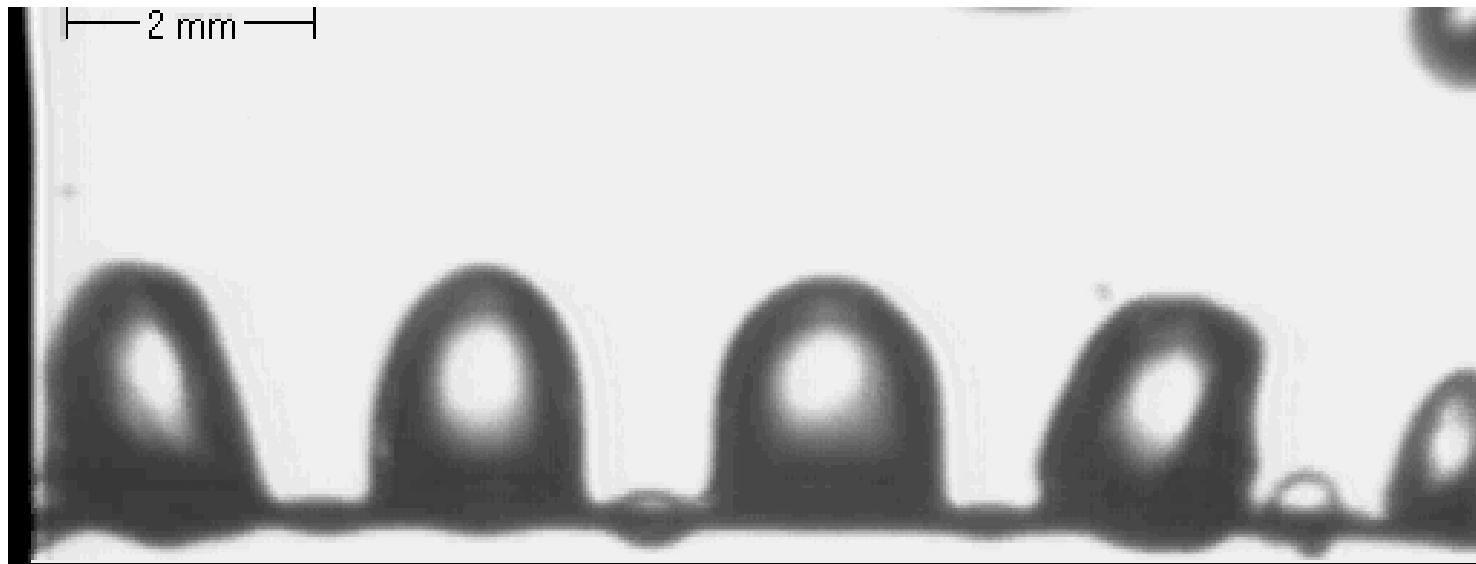


S.M. You, 2002, <http://www-heat.uta.edu/visualization/visualization.html>

Film Pool Boiling from Horizontal Cylinder

$$\overline{Nu}_D = \frac{\bar{h}D}{k_v} = 0.62 \left[\frac{g(\rho_l - \rho_v)(h_{fg} + 0.80c_{p,v}(T_s - T_{sat}))D^3}{v_v k_v (T_s - T_{sat})} \right]^{1/4}$$

Minimum Heat Flux

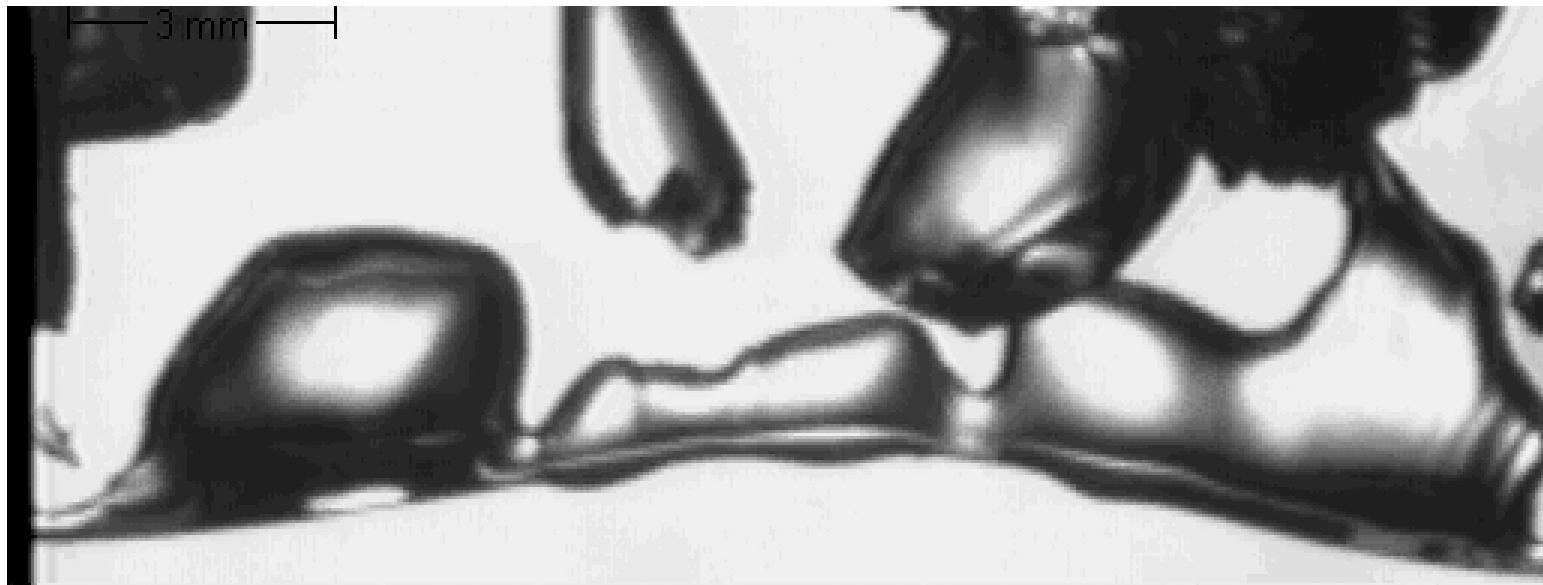


S.M. You, 2002, <http://www-heat.uta.edu/visualization/visualization.html>

Correlation CHF Nucleate Pool Boiling

$$q_{\max} = 0.09 h_{fg} \rho_v \left[\frac{\sigma g (\rho_l - \rho_v)}{(\rho_l + \rho_v)^2} \right]^{1/4}$$

Heater Wire Burnout



S.M. You, 2002, <http://www-heat.uta.edu/visualization/visualization.html>

High Speed Video Imaging:

S. M. You

Professor Mechanical & Aerospace Engineering Department

University of Texas at Arlington

Forced Convection Boiling

Forced Convection increases the heat transfer coefficient for boiling including the critical heat flux.

Low Velocity

$$q_{\max}'' = h_{fg} \rho_v V \cdot \frac{1}{\pi} \left[1 + \left(\frac{4\sigma}{\rho_v V^2 D} \right) \right]^{1/4}$$

High Velocity

$$q_{\max}'' = h_{fg} \rho_v V \cdot \left[\frac{\left(\rho_l/\rho_v\right)^{3/4}}{169\pi} + \frac{\left(\rho_l/\rho_v\right)^{1/2}}{19.2\pi \left(\frac{\rho_v V^2 D}{\sigma} \right)^{1/3}} \right]$$

Two Phase Heat Transfer

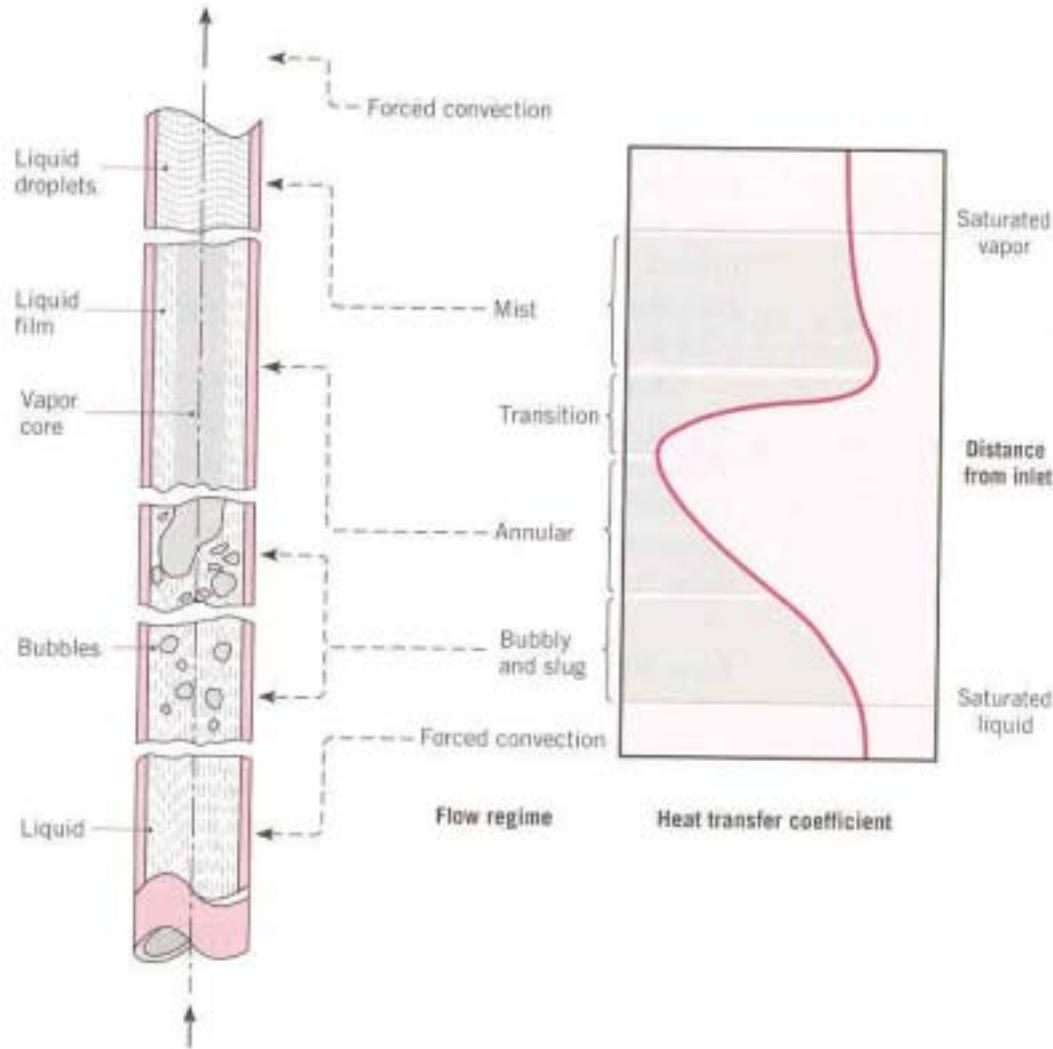


FIGURE 10.9 Flow regimes for forced convection boiling inside a tube,

Condensation

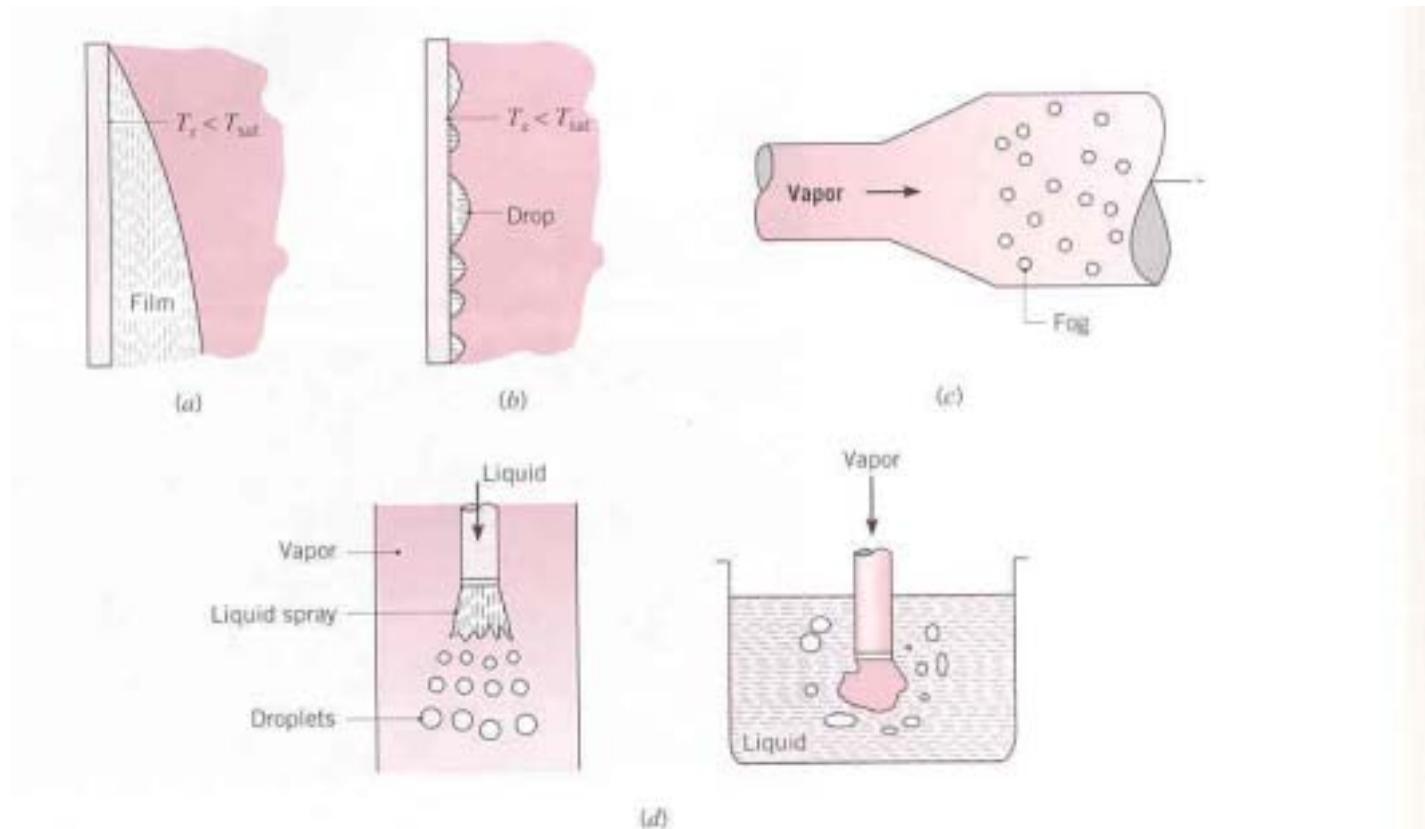


FIGURE 10.10 Modes of condensation. (a) Film. (b) Dropwise condensation on a surface. (c) Homogeneous condensation or fog formation resulting from increased pressure due to expansion. (d) Direct contact condensation.